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SUCCESSFUL APPLICATION OF LOW LOSS, OVER-MODED WR-187 WAVEGUIDE--ETC(U)
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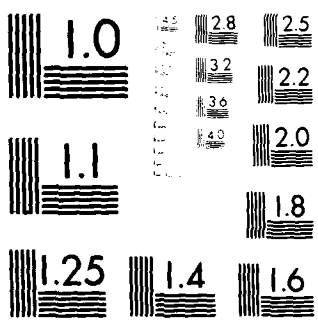

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Development Service
Washington DC 20590

Successful Application of Low Loss, Over-Moded WR-187 Waveguide to the ASDE-3 Radar

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April 1982
Final Report

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16. Abstract

Overmoded WR-187 waveguide has been incorporated into the short-range ASDE-3 system to provide a low-loss interconnection between the antenna and the transmitter/receiver.

WR-62 to WR-187 transitions and WR-187 mode suppressors were developed specifically for this short-range radar application to provide low loss transmission of 0.01 dB per ft.

The 36-nanosecond, 160-dB dynamic range ASDE-3 system is operating without resonance effects down to the required minimum radar range of 500 ft.

This report presents pertinent technical detail and briefly describes the testing process.

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Preface

The activity described in this report was performed to provide a low loss waveguide interconnection between the antenna and the transmitter/receiver of the ASDE-3 radar.

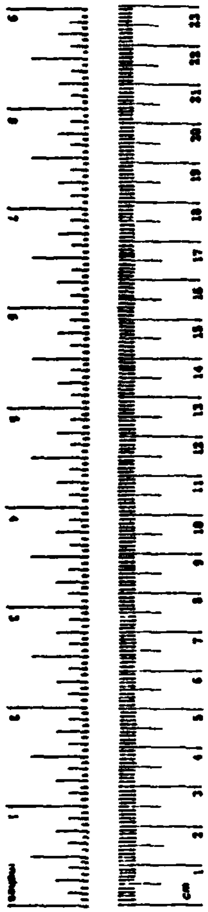
The efforts of Frank LaRussa, Transportation Systems Center, and Tore Anderson, A.J. Tuck Company, Brookfield Ct who contributed to the successful completion of this phase of the ASDE-3 program are acknowledged and appreciated.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

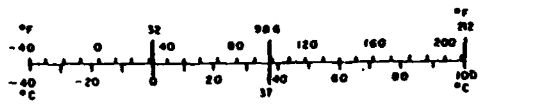
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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SUCCESSFUL APPLICATION OF LOW LOSS, OVERMODED WR-187 WAVEGUIDE TO THE ASDE-3 RADAR

1. INTRODUCTION

Over-moded waveguides have long promised low transmission line losses so important to the radar system designer because of its two-way system loss, on transmit and receive. Trapped higher order mode resonances have heretofore prevented successful application of this potential.

On 15th April 1980, the first known U.S. application of overmoded rectangular waveguide, WR-187 operating cross polarized in the TE_{01} mode at 16 GHz, was successfully accomplished at the FAA Technical Center, Atlantic City Airport NJ.[1] The radar tower and installation are shown in Figure 1. The mode suppression was adequate to allow radar operation of this 35-nanosecond system at a dynamic range of 160 dB in less than 1 microsecond. Use of oversized circular waveguide, which was attempted earlier, was unsuccessful due to the inability to solve the associated higher order mode ringing problems. Calculated and measured loss in WR-187 was only 1.0 dB per 100 ft, compared to 5.0 dB in WR-62 for OFHC copper waveguide. The return loss of this oversized waveguide system was better than 40 dB (1.01VSWR), compared to 20 dB for a typical WR-62 run (1.2 VSWR).

[1] A practical 1981 review of the State of the Art of Low Loss Transmission Using Over-Moded Waveguide by Tore N. Anderson was presented at the IEEE AP/MTT-S Philadelphia Section Benjamin Franklin 1981 Symposium by Tore N. Anderson.

2. WR 187 TE_{01} OPERATION [2]

Mode suppressors and Gaussian transitions from WR-62 (TE_{10}) to WR-187 (TE_{01}) were designed and electroformed by the A. J. Tuck Co., Brookfield CT 06804, to meet the required application. The hardware is shown in Figure 2. Using the transitions and WR-187 waveguide, the modes listed in Table I could be generated and propagated. Consequently, mode suppressors were fabricated to suppress the undesired modes. Figure 3 indicates the technique used to suppress all but one of the undesired modes. Five metallized mica resistance cards were mounted in grooves electroformed in place. These suppress all the TE_{10}, TE_{20}, and TE_{30} modes, as well as the TE_{mn}/TM_{mn} (m & n, O), very effectively with very low loss to the desired TE_{01} mode, i.e., less than 0.04 dB. The TE_{02} mode, however, is not affected by these cards and it was necessary to couple out this modal energy by the slot coupler shown in Figure 4.

Low-level measurements tabulated in Table II indicate that these techniques are useable over the full WR-62 waveguide band. Return loss for this transmission line is 30 dB at 12.4 GHz (1.06 VSWR), 35 dB at 14 GHz (1.04), and better than 40 dB from 15 to 18 GHz (1.02).

3. PROCUREMENT PROCESS

The first attempt to employ oversized waveguide utilized WC109 circular waveguide. The moding problems which occurred produced multiple radar returns far beyond the

[2]REFERENCE: U.S. Patent 3,218.586, K. I. Khoury (DECCA), 16 Nov. 1965.

minimum range of the ASDE-3. Concentrated efforts were made to find a practical solution for field use in an operational radar. No viable solution for use with circular or elliptical waveguides was developed.

Effort was then concentrated on application of oversized rectangular waveguide to provide low-loss transmission line between the transmitter/receiver and the antenna. The approach described in this report was implemented after discussions between DOT/TSC and DECCA, Limited, London, England, who hold the referenced patent. A specification, shown in Table III and suitable for ASDE-3 operation, was developed by DOT/TSC. A contract was awarded to the A. J. Tuck Company to design and fabricate transitions and mode absorbers, and provide suitable WR-187 waveguide lengths for the radar tower installation. The hardware was tested at low power levels at the factory and then moved to the FAA Technical Center for on-site testing with the ASDE-3 transmitter/receiver.

4. INSTALLATION AND TEST WITH THE ASDE-3

The transitions, mode absorbers, and WR-187 waveguide were set up and tested at the Atlantic City Airport site of the ASDE-3. The tests were performed in two segments.

In the first segment, the waveguide run was laid out horizontally and terminated by a high power WR-62 termination. The waveguide was fed by the ASDE-3 transmitter/receiver subsystem. The line under test consisted of 75 ft of WR-187 waveguide, two WR-62-to-WR-187 gaussian taper transitions, and various combinations of the mode absorbers which are shown in Figure 2. The best results were achieved using four mode absorbers, two with resistance cards and two without resistance cards. The resonance free effect produced on the radar display is shown

in Figure 5. The waveguide was bent in both the E and H planes with no noticeable change in performance. The insertion loss of the entire waveguide run including transitions and mode absorbers was 0.96 dB at 16 GHz. Allotting 0.2 dB for the transitions and mode absorbers, the WR-187 OFHC copper waveguide attenuation is essentially 1 dB per 100 ft. The insertion loss of WR-62 OFHC copper waveguide is 5 dB per 100 ft. The net one-way reduction in insertion loss for the 80-ft waveguide run would be approximately 3 dB. This was verified after installation to the tower.

The second segment was accomplished when the waveguide was interconnected between the transmitter/receiver at ground level and the antenna rotating at 120 ft above ground level. Similar resonance-free performance was achieved in actual field operation of the ASDE-3 for the operational range requirement of 500 ft to 3 nautical miles. The insertion loss from the transmitter/receiver through the rotary joint to the antenna was measured at 3.3 dB which verified the anticipated reduction in transmission loss.

5. CONCLUSIONS

Low-loss interconnection between the transmitter/ receiver and antenna can be achieved using oversize rectangular waveguide in the TE_{01} mode. Use of oversize rectangular waveguide rather than oversize circular or elliptical waveguide is recommended to provide effective control of higher order modes which would otherwise obscure radar returns in the ASDE-3 radar.

TABLE 1. Waveguide Modes in WR-187 With Cutoff Frequency Below 16.2 GHz

Mode	Cutoff Freq. GHz
TE_{10}	3.152
TE_{20}	6.305
TE_{01}*	6.768
TE_{11}/TM_{11}	7.466
TE_{21}/TM_{21}	9.250
TE_{30}	9.457
TE_{31}/TM_{31}	11.629
TE_{02}	13.535
TE_{12}/TM_{12}	13.898
TE_{22}/TM_{22}	14.932

* Desired Mode

Table 2. Low Power Level K_u-Band Measurements

Freq. GHz.	Total Loss dB	Transition and Mode Absorber	Total	Waveguide Loss dB/Ft.	Theoretical Waveguide loss, dB/ft.
12.4	.42	.28 dB	.14	.012	.012
16.0	.36	.24 dB	.12	.010	.0098
18.0	.31	.20 dB	.11	.009	.0092

TABLE 3. Specification For WR-187 Low Loss Transmission Line For ASDE-3 Radar

1. SCOPE

1.1 Scope - The equipment specified herein is a low loss waveguide transmission line system for use with the ASDE-3 Radar. It connects the transmitter output to the antenna and provides alow loss transmission path for the 15.7 GHz microwave signal between these two points. It utilizes over-sized cross-moded rectangular waveguide, and consists of transitions mode suppressors and straight sections of wr-187 rectangular waveguide.

2. APPLICABLE DOCUMENTS

2.1 General - The following specifications, standards and other documentation form part of this specification and are applicable where pertinent.

2.1.1. Military Specifications

MIL HDBK-216 RF Transmission Lines and Fittings
MIL-F-3922/52B Flanges, Waveguide

3. REQUIREMENTS

3.1 Summary of Components to be Furnished by the Contractor

The contractor shall furnish the quantity of low loss waveguide transmission line componetns specified in the contract. Each system shall be complete in accordance with all relevant specifications and shall include the major items tabulated below.

a. Transitions
b. Mode Suppressors
c. Rectangular Waveguide sections with gaskets and hardware

3.1.1 Transition - The transition shall be of high conductivity copper and shall provide a transition for the TE_{10} mode in WR-62 rectangular waveguide to the TE_{01} in WR-187 rectangular waveguide.

The WR-62 end of the transition shall have a UG-419/U cover flange.

The WR-187 end of the transition shall have a CPR-187G flange. The CPR-187G flange shall have an alignment pin and hole to assure proper alignment of the transition with the mating waveguide.

In the frequency range 15.7 GHz, the transition shall meet the following electrical requirements:

a.	VSWR	1.1:. or less
b.	Insertion Loss:	.1 dB
c.	Spurious Modes:	35 dB or more below the level of the desired mode

3.1.2 Mode Suppressor - The mode suppressor shall be of high conductivity copper and shall attenuate all spurious TE and TM modes in WR-187 size waveguide. It shall have a CPR-187G flange on each end. Each flange shall have an alignment pin and hole to assure proper alignment of the suppressor with the mating waveguide.

In the frequency range 15.7 GHz to 16.2 GHz, the mode suppressor shall meet the following electorial requirements:

a.	VSWR	1.2:1 or less
b.	Insertion Loss:	.2 dB
c.	Spurious Modes:	The effectiveness of the mode suppressor in attenuating spurious modes shall be determined by observing its performance in a low loss transmission line run. In a 70 foot run of WR-187 waveguide with a transition and mode suppressor at each end, ringing" due t o spurious modes shall be 150 dB or more below the level of the desired TE_{01} mode within 1 u sec of the trailing edge of a 40 n sec transmitted pulse.

3.1.3 Rectangular Waveguide - The transmission line shall be WR-187 OFHC copper rectangular waveguide. Each length shall have CPR-187G flanges at each end. These flanges will have an alignment pin and a hole to assure proper alignment of the waveguide sections.

Figure 1. ASDE-3 Radar Tower and Installation at FAA Technical Center

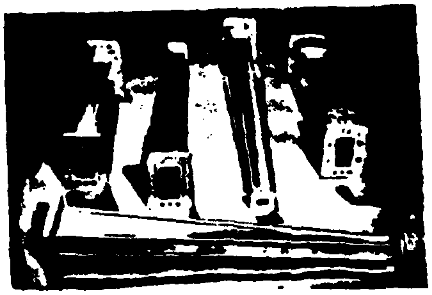

Figure 2. WR-62 to WR-187 Transitions With Higher Order Mode Suppressors

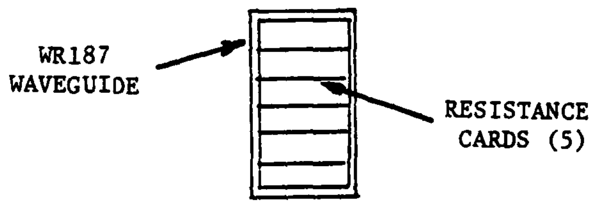

Figure 3. WR-187 Waveguide Multi-Mode
Mode Suppression Using Resistance Cards

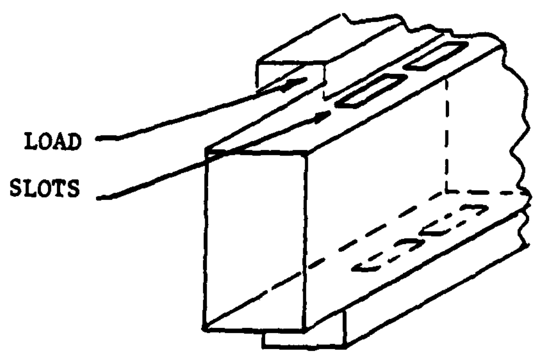

Figure 4. WR-187 Waveguide TE_{02}
Mode Suppression Using Loaded Slots

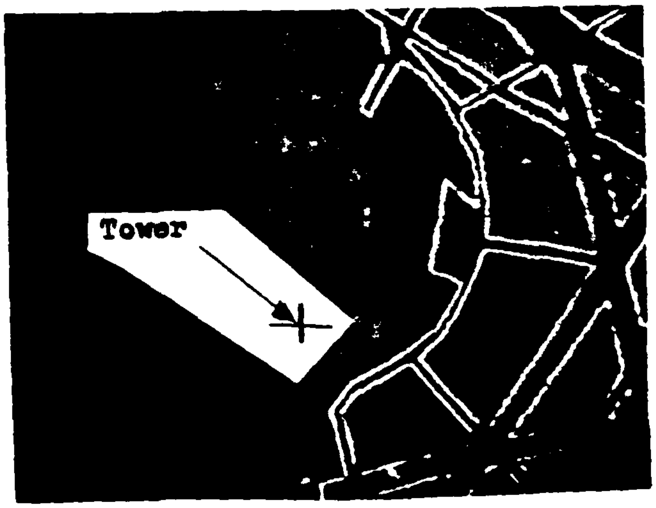

Figure 5. ASDE-3 Radar Display With Low Loss Transmission Line Showing Absence of Ringing

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